Amendments to the Claims:

This listing of the claims will replace all prior versions, and listings, of claims in the application:

Listing of Claims:

Claim 1 (original): A method of conditioning a planarizing surface in a chemical mechanical polishing (CMP) apparatus having a polishing pad against which a wafer is positioned for removal of material therefrom and a conditioning disk is positioned for conditioning of the polishing pad, comprising the steps of:

    a) providing a pad wear and conditioning model that defines wafer material removal rate as a function of at least one pad conditioning parameters, said at least one conditioning parameter having maximum and minimum values;

    b) polishing a wafer in the CMP apparatus under a first set of pad conditioning parameters selected to maintain wafer material removal rates within preselected minimum and maximum removal rates;

    c) determining a wafer material removal rate occurring during said polishing step;

    d) calculating updated pad conditioning parameters based upon said determined wafer material removal rate of said step (c) and the pad wear and conditioning model to maintain wafer material removal rates within the maximum and minimum removal rates; and

    e) conditioning the polishing pad using the updated conditioning parameters.

Claim 2 (original): The method of claim 1, wherein the conditioning parameters comprise conditioning down force.

Claim 3 (original): The method of claim 2, wherein the conditioning parameters comprise rotational velocity of the conditioning disk.

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Claim 4 (original): The method of claim 2, wherein the conditioning parameters comprise one or more parameters selected from the group consisting of rotational velocity of the disk, frequency of conditioning, duration of conditioning and translational speed of the conditioning disk.

Claim 5 (original): The method of claim 1, wherein the step of calculating updated conditioning parameters includes calculating parameters such that the parameter is within the determined minimum and maximum values.

Claim 6 (original): The method of claim 1, wherein the updated pad conditioning parameters are calculated by determining the difference between an output of the pad wear and conditioning model and said determined wafer material removal of step (c).

Claim 7 (original): The method of claim 6, wherein said difference is adjusted using an estimate gain prior to calculating updated conditioning parameters.

Claim 8 (original): The method of claim 1, wherein the updated pad conditioning parameters are updated according to the equation $k = (k_1) + g * (k - (k_1))$, where k is a measured wafer material removal rate, k_1 is a calculated wafer material removal rate, g is the estimate gain, and (k-(k_1)) is the prediction error.

Claim 9 (original): The method of claim 1, wherein the steps b) through e) are repeated.

Claim 10 (original): The method of claim 1, wherein the first set of pad conditioning parameters are determined empirically.

Claim 11 (original): The method of claim 1, wherein the first set of pad conditioning parameters are determined using historical data.

Claim 12 (original): The method of claim 1, wherein the first set of pad conditioning parameters are determined using the results of a design of experiment (DOE) used to develop the model.

Claim 13 (original): The method of claim 1, wherein the maximum value for wafer material removal rate is the saturation point of the wafer material removal rate vs. conditioning down force curve.

Claim 14 (original): The method of claim 1, wherein the minimum value for wafer material removal rate is defined by the maximum acceptable wafer polishing time.

Claim 15 (original): The method of claim 1, wherein the step of calculating updated pad conditioning parameters in step (d) comprises executing a recursive optimization process.

Claim 16 (original): The method of claim 7, wherein the estimate gain is an indication of variability or reliability in the measured parameter.

Claim 17 (original): The method of claim 1, wherein pad life is defined according to the equation:

$$PadLife = f\left(F_{disk}, \omega_{disk}, t_{conditioning}, f, T_2\right),$$

where F_{disk} is the down force applied by the conditioning disk to the CMP pad during conditioning, ω_{disk} is the angular velocity of the conditioning disk during conditioning of the polishing pad, t is the time of conditioning, f is the frequency of condition and T_2 is the sweeping speed of the conditioning disk during conditioning.

Claim 18 (original): The method of claim 1, wherein the wafer material removal rate is defined by the equation

$$\text{Re}\,movalRate]_{\min}^{\max} = f\left(F_{disk}]_{\min}^{\max}, \omega_{disk}]_{\min}^{\max}, f]_{\min}^{\max}, t_{conditioning}]_{\min}^{\max}, T_2]_{\min}^{\max}\right),$$

where F_{disk} is the down force applied by the conditioning disk to the CMP pad during conditioning, ω_{disk} is the angular velocity of the conditioning disk during conditioning of the polishing pad, t is the time of conditioning, f is the frequency of condition, and T_2 is the sweeping speed of the conditioning disk during conditioning.

Claim 19 (original): The method of claim 1, wherein the wafer material removal rate is determined according to the equation:

$$\hat{y}_i = \rho_i x_i + I_i,$$

where $\hat{y}_i$ is the wafer material removal rate for a conditioning parameter x_i, ρ_i is the slope and I_i is the intercept of the curve of the defining the relationship between $\hat{y}_i$ and x_i.

Claim 20 (original): The method of claim 19, wherein the updated pad conditioning parameter, x_{i+}, is determined by solving the equation:

$$x_{i+} = \frac{\hat{y}_{i+} - I_i - \dfrac{W_i}{W_T} \cdot \Delta\hat{y}}{\rho_i},$$

where $\hat{y}_{i+}$ is the target wafer material removal rate, W_i is the weighing factor for conditioning parameter x_i, and Δy is the prediction error for wafer material removal rate.

Claim 21 (original): An apparatus for conditioning polishing pads used to planarize substrates by the removal of material therefrom, comprising:

a carrier assembly having an arm positionable over a planarizing surface of a polishing pad;

a conditioning disk attached to the carrier assembly; and

an actuator capable of controlling an operating parameter of the conditioning disk;

a controller operatively coupled to the actuator, the controller operating the actuator to adjust the operating parameter of the conditioning disk as a function of a pad wear and conditioning model, the model comprising:

determining wafer material removal rate as a function of pad conditioning parameters including conditioning disk down force and conditioning disk rotation rate.

Claim 22 (original): The apparatus of claim 21, wherein the wafer material removal rate is determined according to the equation:

$$\hat{y}_i = \rho_i x_i + I_i,$$

where $\hat{y}_i$ is the wafer material removal rate for a conditioning parameter x_i, ρ_i, is the slope
and I_i is the intercept of the curve of the defining the relationship between $\hat{y}_i$ and
x_i.

Claim 23 (original): The apparatus of claim 22, wherein the updated pad conditioning parameter,
x_{i+}, is determined by solving the equation:

$$x_{i+} = \frac{\hat{y}_{i+} - I_i - \dfrac{W_i}{W_T} \cdot \Delta \hat{y}}{\rho_i},$$

where $\hat{y}_{i+}$ is the target wafer material removal rate, W_i is the weighing factor for
conditioning parameter x_i, and Δy is the prediction error for wafer material
removal rate.

Claim 24 (currently amended): The apparatus of claim 21, wherein the updated pad conditioning
parameters are updated according to the equation ~~$k = (k-1) + g * (k - (k-1))$~~, $\underline{k = (k_1) + g}$
$\underline{* (k - (k_1))}$, where k is a measured wafer material removal rate, $k-1$ is a calculated wafer
material removal rate, g is the estimate gain, and ~~$(k-(k-1))$~~ $\underline{(k-(k_1))}$ is the prediction error.

Claim 25 (currently amended): A method of developing a pad wear and pad conditioning model
for optimization of the pad conditioning, comprising the steps of:

determining the relationship between at least one pad conditioning parameter and
wafer material removal rate; [[and]]

determining maximum and minimum values for each of the at least one pad
conditioning parameters and the wafer material removal rate; and

recording the relationships and minimum and maximum values of the at least one
pad conditioning parameter and the wafer removal rate.

Claim 26 (original): The method of claim 25, wherein the at least one pad conditioning
parameter comprises a plurality of parameters and the wafer removal rate is defined as a
weighted function of the plurality of pad conditioning parameters.

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Claim 27 (original): The method of claim 25, wherein the at least one pad conditioning parameters comprises conditioning disk down force.

Claim 28 (original): The method of claim 27 wherein the at least one pad conditioning parameter further comprises conditioning disk rotational rate.

Claim 29 (original): The method of claim 25, where the at least one pad conditioning parameter comprises one or more parameters selected from the group consisting of conditioning disk down force, conditioning disk rotational rate, frequency of conditioning, and conditioning disk translational speed.

Claim 30 (original): The method of claim 25, wherein the relationship between the at least one conditioning parameter and wafer removal rate is determined by incrementally varying the conditioning parameter and measuring the resultant wafer removal rate.

Claim 31 (original): The method of claim 25, wherein the maximum value for the conditioning parameter is the value above which no incremental increase of the wafer removal rate is observed.

Claim 32 (original): The method of claim 25, wherein the minimum value for the conditioning parameter is the value which provides the minimum wafer removal rate.

Claim 33 (original): The method of claim 25, further comprising the steps of:

       polishing a wafer in the CMP apparatus under a first set of pad conditioning parameters selected to maintain wafer material removal rates within preselected minimum and maximum removal rates;

       determining a wafer material removal rate occurring during said polishing step;

       calculating updated pad conditioning parameters based upon said determined wafer material removal rate and the pad wear and conditioning model to maintain wafer material removal rates within the maximum and minimum removal rates; and

       conditioning the polishing pad using the updated pad conditioning parameters.

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Claim 34 (original): The method of claim 33, wherein the updated pad conditioning parameters are calculated by determining the difference between an output of the pad wear and conditioning model and said determined wafer material removal.

Claim 35 (currently amended): The method of claim 33, wherein the updated pad conditioning parameters are updated according to the equation $k = (k-1) + g * (k - (k-1));$ $k = (k_1) + g * (k - (k_1)),$ where k is a measured wafer material removal rate, k_1 is a calculated wafer material removal rate, g is the estimate gain, and $(k-(k_1))$ is the prediction error.

Claim 36 (original): A computer readable medium comprising instructions being executed by a computer, the instructions including a computer-implemented software application for a chemical mechanical polishing process, the instructions for implementing the process comprising the steps of:

> a) receiving data from a chemical mechanical polishing tool relating to the wafer removal rate of at least one wafer processed in the chemical mechanical polishing process; and

> b) calculating, from the data of step (a), updated pad conditioning parameters within defined maximum and minimum values, wherein the updated pad conditioning parameters are calculated by determining the difference between an output of a pad wear and conditioning model and the data of step (a).

Claim 37 (currently amended): A method of conditioning a planarizing surface in a chemical mechanical polishing (CMP) apparatus having a polishing pad against which a wafer is positioned for removal of material therefrom and a conditioning disk is positioned for conditioning of the polishing pad, comprising the steps of:

> (a) developing a pad wear and pad conditioning model by:

>> (i) determining the relationship between at least one pad conditioning parameter and wafer material removal rate; [[and]]

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(ii) determining maximum and minimum values for each of the at least one pad conditioning parameters and the wafer material removal rate; and

~~(ii)~~ (iii) recording the relationships and minimum and maximum values of the at least one pad conditioning parameter and the wafer removal rate.

(b) polishing a wafer in the CMP apparatus under a first set of pad conditioning parameters selected to maintain wafer material removal rates within preselected minimum and maximum removal rates;

(c) determining a wafer material removal rate occurring during said polishing step;

(d) calculating updated pad conditioning parameters based upon said determined wafer material removal rate of said step (b) and the pad wear and conditioning model to maintain wafer material removal rates within the maximum and minimum removal rates,

wherein the wafer material removal rate is determined according to the equation:

$$\hat{y}_i = \rho_i x_i + I_i,$$

where $\hat{y}_i$ is the wafer material removal rate for a conditioning parameter x_i, ρ_i, is the slope and I_i is the intercept of the curve of the defining the relationship between $\hat{y}_i$ and x_I, and the updated pad conditioning parameter, x_{i+}, is determined by solving the equation:

$$x_{i+} = \frac{\hat{y}_{i+} - I_i - \dfrac{W_i}{W_T} \cdot \Delta\hat{y}}{\rho_i},$$

where $\hat{y}_{i+}$ is the target wafer material removal rate, W_i is the weighing factor for conditioning parameter x_i, and Δy is the prediction error for wafer material removal rate; and

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(e) conditioning the polishing pad using the updated conditioning parameters.

Claim 38 (original): A system for conditioning a planarizing surface in a chemical mechanical polishing (CMP) apparatus having a polishing pad and a conditioning disk, comprising:

a) a pad wear and conditioning model that defines wafer material removal rate as a function of at least one pad conditioning parameters including rotation and direction of the conditioning disk;

b) polishing means for polishing a wafer in the CMP apparatus;

c) measuring means for determining a wafer material removal rate; and

d) calculating means for updating pad conditioning parameters based upon said determined wafer material removal rate of said step (c) and the pad wear and conditioning model to maintain wafer material removal rates within the maximum and minimum removal rates.

Claim 39 (new): An apparatus for conditioning a planarizing surface in a chemical mechanical polishing (CMP) apparatus having a polishing pad and a conditioning disk, comprising:

means for providing a pad wear and conditioning model that defines wafer material removal rate as a function of at least one pad conditioning parameters, said at least one conditioning parameter having maximum and minimum values;

means for polishing a wafer in the CMP apparatus under a first set of pad conditioning parameters selected to maintain wafer material removal rates within preselected minimum and maximum removal rates;

means for determining a wafer material removal rate occurring during polishing;

means for calculating updated pad conditioning parameters based upon said determined wafer material removal rate occurring during polishing and the pad wear and conditioning model to maintain wafer material removal rates within the maximum and minimum removal rates; and

means for conditioning the polishing pad using the updated conditioning

parameters.